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THE VEGETATION OF PEQUAWKET BOG, OSSIPEE, NEW HAMPSHIRE

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ABSTRACT

Peatlands, while ecologically interesting and abundant in the northeast, have gone largely unstudied in New Hampshire. This baseline study focuses on a vegetation analysis of the vascular flora of Pequawket Bog, Ossipee, New Hampshire. A total flora of 109 species, including *Eriophorum angustifolium*, an endangered plant species for the state of New Hampshire, was documented for the bog. Using stratified random sampling, 287 plots from 10 transects were sampled for percent cover of vascular plant species. Five vegetation cover types and nine subtypes were determined using the computer classification program TWINSPAN. The five cover types include: a *Nymphaea odorata* cover type, a *Carex lasiocarpa* cover type, a *Chamaedaphne calyculata-Woodwardia virginica* cover type, a *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum* cover type, and an *Acer rubrum-Vaccinium corymbosum-Lyonia ligustrina* cover type.

Key Words: bog, peatland, plant community, plant classification, New Hampshire, vegetation.

INTRODUCTION

Peatlands occur widely, developing chiefly in cool to cold regions, and often vary considerably in physical character, nutrient status, and vegetation and floristic composition. Gore (1983b) provides a detailed account of peatlands on a worldwide level. As a result of the wide geographic distribution of peatlands, there is a plethora of terms and classification schemes associated with these ecosystems. Moore and Bellamy (1974), Stanek (1977), Worley and Sullivan (1980), Worley (1981), and Gore (1983a) discuss and clarify this often overwhelming aspect of peatland studies. In general,

Figure 1. Aerial photograph of Pequawket Bog, looking north (October, 1991)

peatlands of the northern hemisphere are often referred to as "mires" in Europe (Moore and Bellamy, 1974), "muskegs" in Canada (Stanek, 1977) or simply "bogs" in the United States.

Peatlands may be defined as "three-dimensional portions of the earth's landscape that are wetlands; have organic soils; include the full depth of the organic materials, regardless of origin; include all waters within or on top of the organic materials; and include all organisms living within or atop the organic materials and water" (Worley and Sullivan 1980, pp. 13-14). In this definition the term "wetland" is used as defined by Cowardin *et al.* (1979) for the U.S. Fish and Wildlife Service, and "organic soils" as defined by the U.S. Soil Conservation Service (Soil Survey Staff, 1975).

Peatlands are frequently classified based on hydrology and nutrient status (Sjors, 1959; Jeglum *et al.*, 1974; Moore and Bellamy, 1974; Worley and Sullivan, 1980), and two major classes are typically distinguished: ombrotrophic and minerotrophic peatlands. Ombrotrophic peatlands receive all their nutrients and water through precipitation only. Consequently, these peatlands are very poor in nutrients and are very acidic. Minerotrophic peatlands, conversely, receive nutrients and water from both surface runoff and groundwater as well as from precipitation. Because the water entering has run over and percolated through mineral soils, these peatlands tend to be relatively nutrient rich and typically less acidic. The amounts and quality of these nutrients vary greatly from one geographic location to another due to a number of factors, including bedrock, soil characteristics, and topography (Gorham, 1956, 1957).

A fundamental distinction is also made between bogs and fens when classification is based on hydrology and nutrients. "True" bogs are strictly ombrotrophic, and the vegetation is typically dominated by *Sphagnum* spp., low ericaceous shrubs, and scattered conifers. Fens, on the other hand, are minerotrophic peatlands and the vegetation is largely dominated by sedges and grasses, with *Sphagnum* spp. functioning in a subordinate role.

While such classification systems appear useful, it is often difficult to classify certain peatlands satisfactorily into one class or the other. This is especially true for kettle-hole or basin peatlands, where nutrient status and hydrology change through successional development (Crum, 1988). At the base of the upland there tends to be a strong minerotrophic influence, yet further away from the edge the peat mat may be essentially ombrotrophic, as the inflowing of waters through the peat is impeded.

Damman and French (1987) prefer not to utilize the term bog in the strict sense, based on the fact that weakly minerotrophic fens are floristically similar to the vegetation of ombrotrophic peatlands, and have few floristic similarities to nutrient-rich fens. In a community profile of peat bogs of the glaciated northeastern United States their term "bog" is used to refer to "peatlands with a well-developed moss carpet dominated by *Sphagnum*" (Damman and French, 1987, p. 1). Other recent ecologists who do not restrict their use of the term "bog" solely to ombrotrophic peatlands include Golet and Larsen (1974), Jeglum *et al.* (1974), Rawinski (1984), and Sperduto (1994).

Damman and French (1987) treat peatlands as landforms and base the divisions on the nature of the water that controls their development. In this scheme four major types are recognized: 1) limnogenous, 2) topogenous, 3) ombrogenous, and 4) soligenous. Limnogenous peatlands occur along lake-margins and slow flowing streams. Topogenous peatlands develop in sites where there is an accumulation of water, and are maintained by a permanent ground water table or seepage; these include kettle hole bogs. Ombrogenous peatlands include raised bogs which form independently from ground water or seepage, and are restricted to humid, cold temperate climates. In eastern North America these occur from northern Maine to Nova Scotia and western Newfoundland. Soligenous peatlands are dependent on minerotrophic seepage water, and are found in regions with high precipitation and less evapotranspiration. These include sloped fens.

Sperduto (1994) classifies peatlands in New Hampshire into three general categories based on nutrient and pH levels: 1) bogs, 2) acidic fens, and 3) calcareous fens, as well as three broad climatic influences: coastal/southern, boreal/transitional, and alpine/subalpine. Rawinski (1984) classifies as bogs, ombrotrophic to weakly minerotrophic peatlands, and distinguishes between level and raised bogs. Fens, on the other hand, are treated in this classification as peatland communities influenced by seepage waters with alkalinity ranging from low to high. A distinction is also made between calcareous and acidic fens, and whether each is sloping or level.

Although it is often the goal to classify a particular peatland into one specific category, in reality this is not an easy task. It is usually better to treat these ecosystems as peatland complexes comprised of different zones, each with differing nutrient levels and plant associations.

The importance of water chemistry in relation to vegetation in peatlands has been demonstrated in numerous studies (Bay, 1967; Heinselman, 1970; Jeglum, 1971; Moore and Bellamy, 1974; Vitt and Slack, 1975; Schwintzer, 1978, 1981; Wells, 1981; Schwintzer and Tomberlin, 1982; Vitt and Bayley, 1984). Patterns of plant associations in the successional development of kettle-hole peatlands have been shown to correlate strongly to variations in pH (Crow, 1969; Vitt and Slack, 1975; Vitt and Bayley, 1984; Dunlop, 1987).

An important source of acidity in peatlands is the activity of *Sphagnum*. It has been well documented that these mosses have the ability to actively acidify their environment through the process of cation exchange (Clymo, 1963, 1964; Craigie and Maass, 1966), the site of exchange being an unesterified polyuronic acid (Clymo, 1963). Other important sources of acidity include sulfuric and humic acids (Mitsch and Gosselink, 1986). However, "acid rain" apparently does not function as an acidifying agent in peatlands. This acidic input is apparently negated by an increase in alkalinity by sulfate reduction and nitrate uptake (Hemond, 1980).

Numerous descriptive studies have focused on the floristics and phytosociology of peatlands. Some include: Heinselman (1963, 1970) in northern Minnesota; Janssen (1967) in northwestern Minnesota; Conway (1949) in central Minnesota; Hansen (1933) in the driftless area of Wisconsin; Rhodes (1933) in the drift-covered area of Wisconsin; Gates (1942) in northern lower Michigan; Transeau (1905, 1906), Brewer (1966), Crow (1969), and Keogh and Pippen (1981) in southern Michigan; Dansereau and Segadas-Vianna (1952) in eastern Canada; Sjors (1959, 1963) in the Hudson Bay Lowlands, and Attawapiskat River in northern Ontario, respectively; Wells (1981) in Newfoundland; Damman and French (1987) in the glaciated regions of eastern United States; Dunlop (1987) in southern New Hampshire; and Montgomery and Fairbrothers (1963) in New Jersey.

While peatlands are a common and interesting component of the New England landscape, relatively few detailed studies on the major plant cover types of these ecosystems have been conducted. This is especially true in New Hampshire. Johnson (1985) provides a broad overview of peatlands in New England. In Massachusetts, Motzkin and Patterson (1991) investigated vegetation patterns of a moat bog in relation to basin morphometry, Hemond (1980) investigated the biogeochemistry of Thoreau's Bog in Concord, while Swan and Gill (1970) studied the role of *Chamaedaphne calyculata* in the succession of an artificially made kettle hole bog. In

Maine, Worley and Sullivan (1980) and Worley (1981) have focused on classification, while in a northern Vermont peatland complex, Osheyack and Worley (1981) investigated primary production. In New Hampshire, Barrett (1966) studied succession in a southern New Hampshire peatland in relation to physical and edaphic factors. Other peatlands of the state have been used in palynological studies which have focused on post-glacial vegetation during the Holocene (Kraus and Kent, 1944; and Davis *et al.*, 1980). But only one other detailed study of New Hampshire peatland vegetation has been published (Dunlop, 1987).

The purpose of this study is to describe and map the vegetation cover types of Pequawket Bog and to add to our overall base-line information on the vegetation and floristic composition of peatlands in New Hampshire.

STUDY AREA

Pequawket Bog is located in the Town of Ossipee, near the Effingham town line, in Carroll County, New Hampshire. While it has no official name, Pequawket Bog is referred to herein as such because of the historical influence of the Pequawket Indians in the area (Cook, 1989), and its proximity to Pequawket Trail road. Pequawket Trail was originally used by the Pequawket Indians to travel between the regions of Ossipee and Conway (Ruth Loring, pers. comm.). This peatland complex is situated between Long Sands Road and Pequawket Trail Road, off of State Route 25 at 43° 47' N. Lat., 71° 06' W. Long. It lies just southeast of Ossipee Lake at an elevation of approximately 123.7 meters above sea level (406 ft.). The size of the peatland is approximately 9.9 hectares (24.4 acres), including a 2.8 hectare (7 acre) pond. Hellquist (1971) conducted a survey of the aquatic plants of Ossipee Lake and its associate bays, but did not include

Pequawket Bog.

Although it is referred to as a bog, it is more appropriate to classify Pequawket Bog as a peatland complex, as it clearly has two very different zones with a peat substrate, each with a unique floristic character. On the west of the pond is a sedgy meadow, or level fen (Figure 1). The south, east and southwest sides of the pond are characterized as having a more typical bog flora with *Sphagnum* spp. and low ericaceous shrubs dominating.

The upland soils in the general area surrounding the two peatlands are of glacial outwash origin, and are part of the Hinckley-Windsor-Deerfield association characterized as "nearly level to very steep, excessively drained and moderately well drained gravelly and sandy soils; on terraces, kames, and eskers" (Diers and Vieira, 1977, p. 4). The Greenwood-Chocorua-Namburg association is more typical of the lower lying areas and is defined as "nearly level, very poorly drained organic soils and somewhat poorly drained and poorly drained sandy soils; along broad drainageways and depressions" (Diers and Vieira, 1977, p. 5).

The upland area along the eastern border of Pequawket Bog fits the concept of excessively drained soils of the Hinckley series, that are characterized as gravelly loamy sands. The esker to the southwest of the pond in Pequawket Bog is of the Windsor series and is a loamy sand.

The soil within the bog is classified as a Greenwood mucky peat, which is characterized as organic soil composed of partly to well decayed herbaceous and woody material. This organic layer may range from 50 inches to over 10 feet, with an underlying layer of sand, gravel, silt, or loam. According to the Carroll County soil survey (Diers and Vieira, 1977), the area encompassing Pequawket Bog is classed as a fresh water marsh, and broadly defined as a land type covered by shallow water most of the time, found around edges of lakes and ponds and also in depressions that are ponded much of the year. This assessment has been incorrectly applied to the entire peatland complex. While it may be descriptive of the sedgy meadow to the west of the pond, it has been inappropriately applied to the areas south and east of the pond. These are clearly Greenwood mucky peat.

Based on interpretation of the Ecologic Map and Structure Sections of the Ossipee Lake Quadrangle, New Hampshire" (Wilson, 1969) the bedrock which underlies the glaciofluvial deposits around the bog appears to be Conway Granite of the New Hampshire Plutonic Series, which dates back to the Middle Devonian. This rock is generally characterized as: a "medium grained, light-colored, equigranular and contains plagioclase with a composition of about An_{20}, microcline, quartz, biotite, and Muscovite" (Wilson, 1969, p. 26).

The climate in this area can be characterized as having relatively mild summers, cold winters, and abundant rainfall (Diers and Vieira, 1977). The climate is considered continental, mainly influenced by westerly winds, but because of the relative proximity to the Atlantic ocean there is increased precipitation in the fall and winter. Low spots, especially peaty soils, are more frost prone on cold clear nights. The climatological data presented were recorded at the weather station in Conway, approximately 15 miles north of the bog, and are representative of areas within the county at lower elevations. Temperature fluctuations in Carroll County are prone to frequent changes, as the county lies in a region where weather systems tend to alternately bring in warmer and colder air. Weather records (Diers and Vieira, 1977) showed an average annual temperature at Conway (elevation 145 m) of 6.3 °C (43.3 °F), with average annual maximum and minimum temperatures of 13.4 °C (56.1 °F) and -0.8 °C (30.6 °F) respectively. The average annual extreme maximum is 35.6 °C (96 °F) and extreme minimum is -32.2 °C (-26 °F). July is the warmest month averaging 19.7 °C (67.5 °F), with a mean daily maximum of 27.4 °C (81.4 °F) and a mean daily minimum of 12 °C (53.6 °F). The average extreme maximum recorded for July was 33.9 °C (93 °F) and extreme minimum was 3.9 °C (39 °F). January is the coldest month averaging -8.3 °C (17 °F), with a mean daily maximum and minimum of -1.3 °C (29.7 °F) and -15.4 °C (4.3 °F), respectively. The average extreme maximum is 8.3 °C (47 °F) and minimum is -30 °C (-23 °F).

Precipitation is, for the most part, evenly distributed throughout the year, however there tends to be a slight increase in the fall and winter. The area receives an average of 116.9 cm (46.01 in.) annually. The monthly averages range from 14.3 cm (5.64 in.) in November to 7.6 cm (3.00 in.) in January.

Average annual snowfall is 287.8 cm (113.3 in.). The amount varies greatly from year to year, but is seldom less than 143.9 cm (56.65 in.) or more than 431.7 cm (169.95 in.). The first snowfall usually occurs in October, and the ground is normally covered with snow from early December to sometime in April. Even in the mildest winters the ground is rarely bare in January, February, and March.

For most of Carroll County, the frost-free season ranges from 105 to 130 days, and may extend to 140 days in more favorable spots. However, in low areas the frost-free period tends to be shorter.

METHODS

A total inventory of the vascular plant species found in Pequawket bog was initiated in mid-April of 1991 and continued through the growing season to mid-October, 1991. Voucher specimens are deposited in the Hogdon Herbarium (NHA), University of New Hampshire. The account of the flora is published elsewhere (Fahey and Crow, in press).

Quantitative sampling of the Pequawket Bog vegetation began in mid-July and continued to late August, 1991. Stratified random sampling (Mueller-Dombois and Ellenberg, 1974) was employed. Nine transects were placed at relatively equal intervals and positioned as to best sample all vegetation cover types (Figure 2). An additional transect was sampled on the west side of the pond, in an area which was particularly disturbed by beaver, and represented an ecotone between two visually distinctive cover types. This area consists of many deep channels and appeared initially to be somewhat unique in its plant associations. Each transect was divided into 10 meter segments. In areas of low growing vegetation (below 1.5 m) two 1 x 1 meter quadrats were located using random numbers. For areas with tall shrubs or trees over 1.5 meters, one 4 x 4 meter quadrat was sampled per 10 meter segment of transect. In the larger plots, two 1x1 meter quadrats in opposite corners were sampled for the lower vegetation. The lower left and upper right corners were used consistently. The data from the two 1x1 meter quadrats were averaged and combined with the taller shrub data for total plot information. This method is similar to Dunlop's (1987) sampling regime of a southern New Hampshire peatland which was found quite effective. A total of 287 quadrats was sampled for absolute percent cover and species composition. Cover is defined as the crown or shoot area of a species projected over the ground surface. This area is expressed as a percent of the reference area (Mueller-Dombois and Ellenberg, 1974).

The vegetation data were analyzed using TWINSPAN (Two-way Indicator Species Analysis), a FORTRAN program (Hill, 1979). TWINSPAN is a polythetic divisive method of classification, which results in an ordered two-way table based on a series of ordinations. This program has been employed by other ecologists in the analysis of peatland vegetation (Slack *et al.*, 1980; Dunlop, 1987; Vitt *et al.*, 1989). Using all the samples, it begins with the "primary" ordination, made by reciprocal averaging. This ordination is essentially divided in half. It proceeds to the next ordination where species that

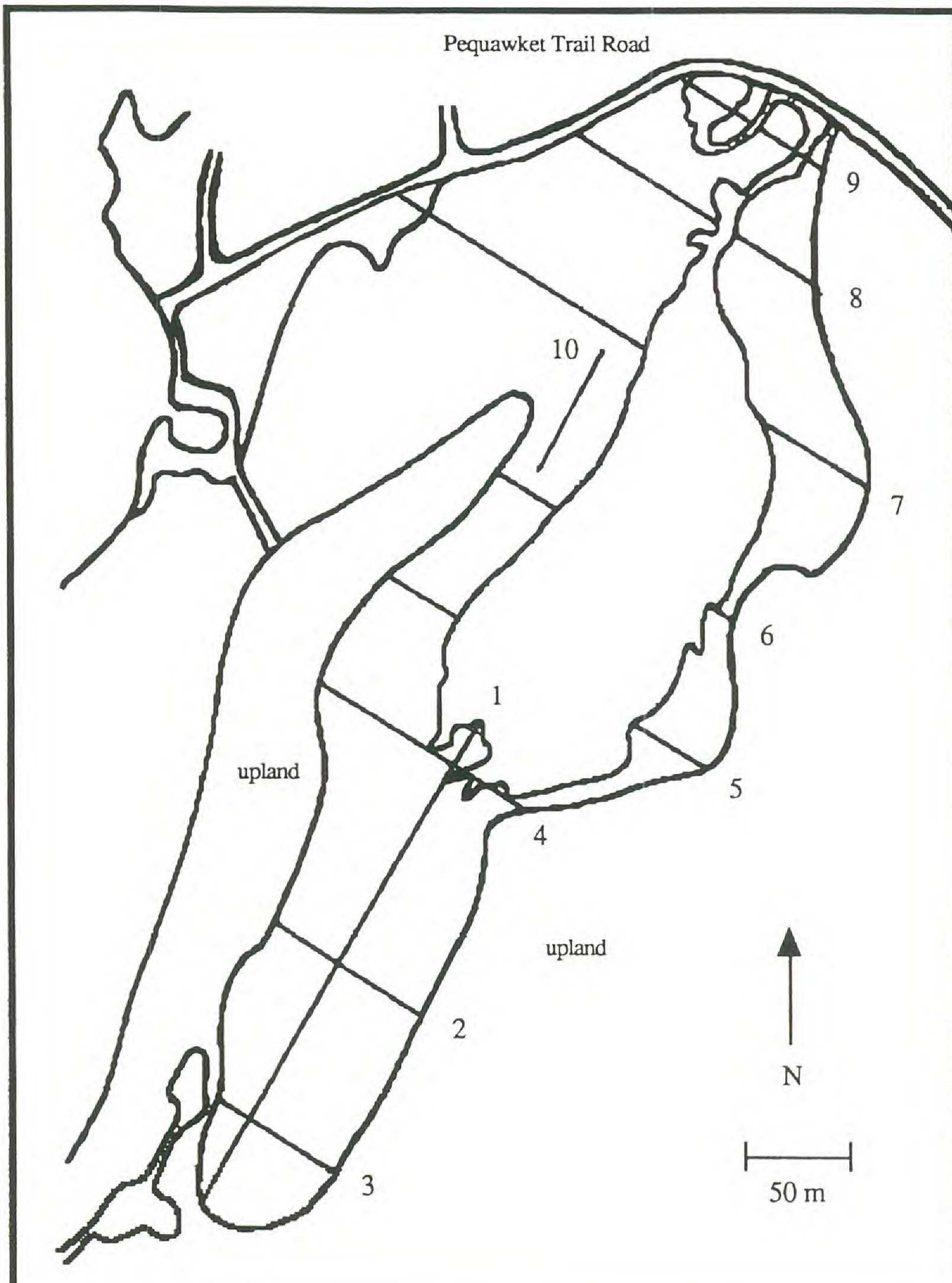

Figure 2. Locations of vegetation sampling transects

show a preference to one side or the other of the initial ordination are identified and used as a basis for this "refined" ordination. These species are referred to as "differential" or "preferential" species, and are said to be showing a preference to certain ecological conditions. The final ordination, the "indicator" ordination, identifies those species that show a particularly high preference to either side of the dichotomy. These species are referred to as "indicator" species. The ultimate dichotomy is based on the refined ordination, while the indicator ordination is simply additional information given to the investigator to further characterize the communities or vegetation types.

The pseudo-species cut levels of 1, 2, 3, 4, 5 represent the Braun-Blanquet cover values 0, 5, 25, 50, 75, respectively, of the Braun-Blanquet system of phytosociology (Hill, 1979). All pseudo-species were available as indicator species, and all cut levels were weighted equally.

In order to plot a profile of the shape of the basin and thickness of organic material, peat depths were measured using a probe of connecting steel rods. At Pequawket Bog, this was measured every 10 meters along transect 1 and transect 8 (Figure 2).

From late-August to mid-September, pH measurements were taken using a VWR Digital Mini pH Meter (model 55). At Pequawkel Bog sites within the peatland that appeared to represent distinct cover types or subtypes were sampled. Five measurements were taken at each site. A total of 25 sites was sampled with a total of 125 samples measured.

Using the TWINSPAN classification as a basis, the average species density (number of species/m^2) for the subtypes and moat cover type were calculated using the data from the 1 m^2 quadrats The means were compared via a one factor ANOVA (Scheffe F-test) for significant differences at the

95% confidence level ($p < 0.05$).

RESULTS AND DISCUSSION

A flora of 109 species was documented for Pequawket Bog. The inventory included a new record of *Eriophorum angustifolium,* an endangered species for the state of New Hampshire (DRED, 1987), and now known from only two localities. A complete account of the floristic inventory is presented elsewhere as it includes a comparison to the floristic composition of a well-known nearby peatland, Heath Pond Bog (Fahey and Crow, in press).

VEGETATION

The TWINSPAN classification of vegetation for Pequawket Bog resulted in a total of five major cover types and nine subtypes, each with a relatively distinct floristic composition and physiognomy (Figure 3). While some of the subtypes are not large enough to map, they are included in the analysis as they may reflect microhabitats found within the peatland. In general, Pequawket Bog is comprised of an aquatic cover type, a sedge meadow or fen cover type, two "typical" bog cover types dominated by ericaceous shrubs, and a tall shrub or moat cover type.

Figure 3 summarizes the TWINSPAN classification of the 287 vegetation samples into five major cover types and nine subtypes at six hierarchical levels; the number of samples clustered into each is indicated. At the first hierarchical level the aquatic, *Nymphaea odorata* cover type (CT I) is distinguished from the total 287 samples. At the second level this cover type was divided further into two subtypes. From the remaining 267 samples, 83 define the *Carex lasiocarpa* cov-

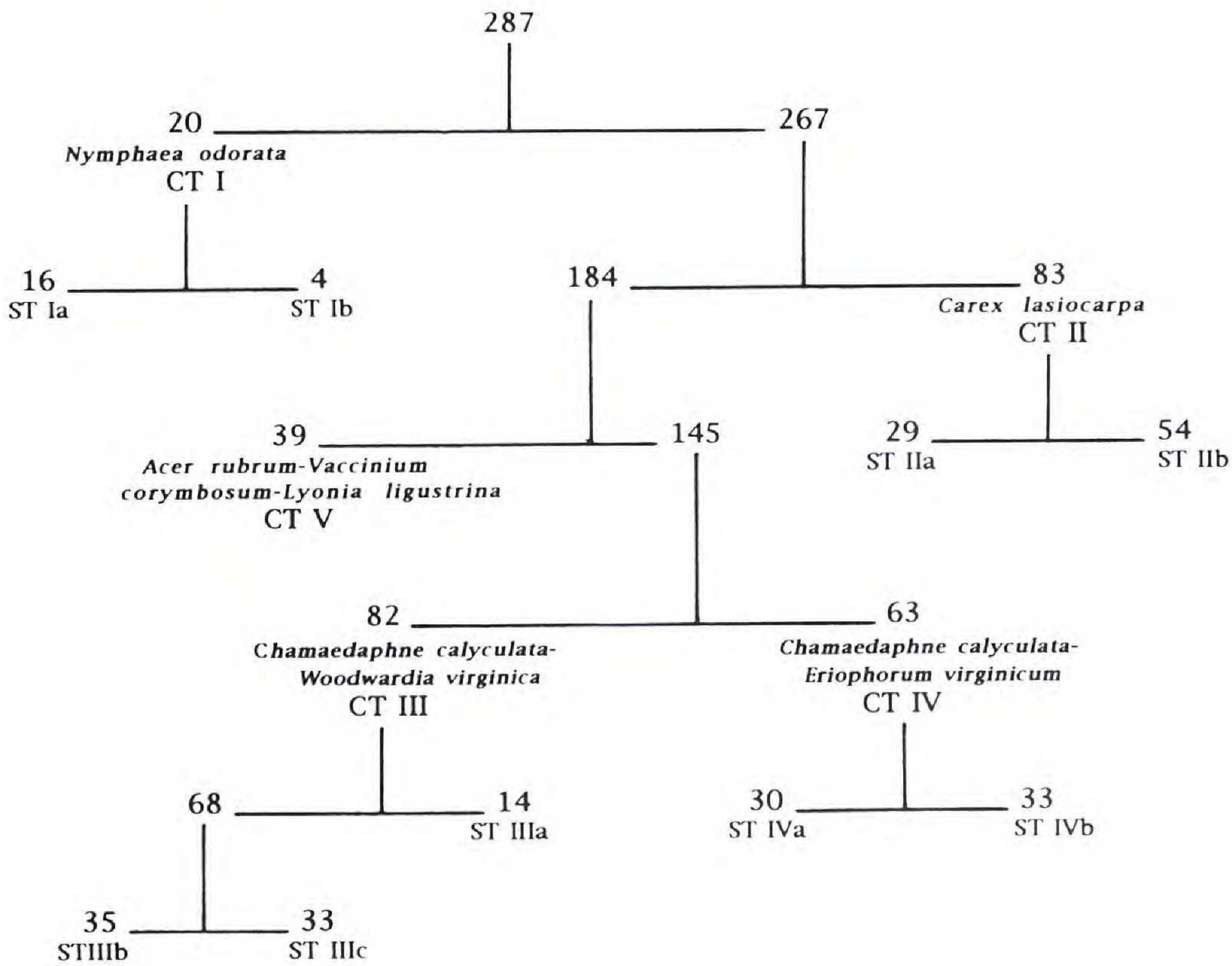

Figure 3. Summary of TWINSPAN analysis showing the separation of 287 quadrat samples into cover types (CT) and subtypes (ST) of Pequawket Bog, and indicating the number of quadrats in each group

er type (CT II) at the second level. This was also divided further into two subtypes. At the third level the remaining 184 samples clustered into *Chamaedaphne calyculata* dominated cover types and the tall shrub, *Acer-Vaccinium corymbosum-Lyonia* cover type (CT V). The *Chamaedaphne calyculata* dominated cover types are classified at the fourth level into the *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III) and the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum* cover type (CT IV). These two cover types are then divided further into subtypes at the fifth and sixth levels (Figure 3).

The naming of the cover types was based primarily on the combined score of mean percent cover and percent frequently of the most dominant species (see tables 1-5). Percent cover and frequency were also tabulated for each subtype (Fahey, 1993), with subtype data presented here for selected species in the discussion.

It should be noted as well that a submerged zone dominated by *Potamogeton amplifolius* was observed in the deeper waters of the pond, particularly toward the south-central end of the pond. This area was not sampled quantitatively. However, it is worth mentioning as it may be an indication of the amount of accumulated sediments in the basin, and the depth of the water.

In the following discussion the cover types and subtypes determined by TWINSPAN for Pequawket Bog are described. Comparisons are also made with nearby Heath Pond Bog (Fahey, 1993) and other North American level peatlands described in the literature. Because this study focuses on vascular plant species, the importance of *Sphagnum* was not included in discussion, although it is understood that the various species of *Sphagnum* play a critical role in peatland ecosystems. Also, it is realized that indicator species from one geographic region may differ considerably from those of other regions.

Nymphaea odorata Cover Type (CT I)

This cover type is dominated by submerged, floating-leaf, and emergent aquatic plants and occurs around the outer pond margin in varying degrees of width. It also occurs in a pooled area at the northern edge of the peatland (Figure 4). *Nymphaea odorata*, *Utricularia purpurea*, and *Eleocharis robbinsii* are the major constituents with the highest cover and frequency values (Table 1). The TWINSPAN program used these as indicator species of this cover type. Other species recognized by TWINSPAN as preferential to this cover type are *Pontederia cordata, Utricularia intermedia*, and *Brasenia schreberi*. This is also reflected in their relatively high cover or frequency values (Table 1). Other species with more patchy distributions in the pond include *Potamogeton confervoides* and *Nuphar variegata*.

The *Nymphaea odorata* cover type of Pequawket Bog has some floristic similarities to the *Nymphaea-Brasenia* zone reported by Dunlop (1987) in Mud Pond Bog, a southern New Hampshire peatland. However, that zone at Mud Pond Bog also was apparently more depauperate than that found at Pequawket Bog, lacking many submerged and emergent species.

Aquatic zones with floristic similarities have also been reported in Michigan peatlands. Crow (1969) described two aquatic associations around a southern Michigan bog. A *Nuphar-Eleocharis* zone dominated the perimeter of the pond, and a *Decodon* zone on one side. Also present were a number of floating and submerged aquatics, including *Utricularia purpurea*, which is quite dominant at Pequawket Bog as well. *Decodon verticillata* was found in Pequawket Bog, but to a very insignificant extent toward the southwest end of the pond. Similarly, a phytosociologic zone dominated by *Nuphar variegata* and other floating-leaved macrophytes was described by Dansereau and Segadas-Vianna (1952).

Table 1. Mean percent cover and percent frequency of dominant and subdominant species in the *Nymphaea ordorata* cover type (CT I).

Species	Mean % Cover	% Frequency
*Nymphaea odorata**	40	95.0
*Utricularia purpurea**	20	60.0
*Eleocharis robbinsii**	14	85.0
Pontederia cordata	8	40.0
Potamogeton confervoides	6	15.0
Brasenia schreberi	2	30.0
Utricularia intermedia	2	30.0
Carex lasiocarpa	2	10.0
Nuphar variegata	1	10.0
Sphagnum spp.	1	10.0

* = indicator species for CTI

Subtype Ia

Within the *Nymphaea odorata* CT, two subtypes could be discerned. The first subtype (ST Ia) is found adjacent to the encroaching mat around the majority of the pond (Figure 4). *Utricularia purpurea* was used by TWINSPAN as the indicator species to distinguish this subtype as it shows a high frequency (75%) in the samples found around the pond as well as the second highest percent cover (25%). Additionally, *Eleocharis robbinsii* showed a high frequency of occurrence (81.3%) and the third highest percent cover (15%). *Nymphaea odorata, Brasenia schreberi, Eleocharis robbinsii*, and *Utricularia intermedia* were also found to be quite frequent in this subtype. It is this mixture of submerged, emergent, and floating-leaved aquatic species which serve as the forerunner of the encroaching mat.

Utricularia purpurea has been reported to be present primarily in bogs which possess a false bottom of muddy, organic sediments (Crum, 1988).

Keough and Pippen (1981) report *Eleocharis robbinsii* present in a southwest Michigan bog, but in an area more characteristic of a moat. There are, however, few reports of the presence of *Eleocharis robbinsii* in other peatlands. This may be due to the fact that descriptions of aquatic communities are often omitted in studies of peatland vegetation because they are not deemed unique to the peatland ecosystem, or, due to their location, are often difficult to sample.

Subtype Ib

The second subtype (ST Ib) is a smaller association found in a pooled area at the northern edge of the peatland along Pequawket Trail Road (Figure 4). This subtype appears relatively depauperate, with a total of four species. But only four sample plots fall into this division. *Pontederia cordata*, with a cover value within STIb of 4% and a 25% frequency, is the most characteristic species of this subtype, and was used by TWINSPAN as an indicator species. *Potamogeton confervoides* was also conspicuous, with a cover value of 30% and a frequency of 50%. *Eleocharis robbinsii,* a plant with a 100% frequency value, seemingly has a low cover value within the subtype (7%) due to the nature of its slender, erect growth form. *Nymphaea odorata* is also a major component of this subtype.

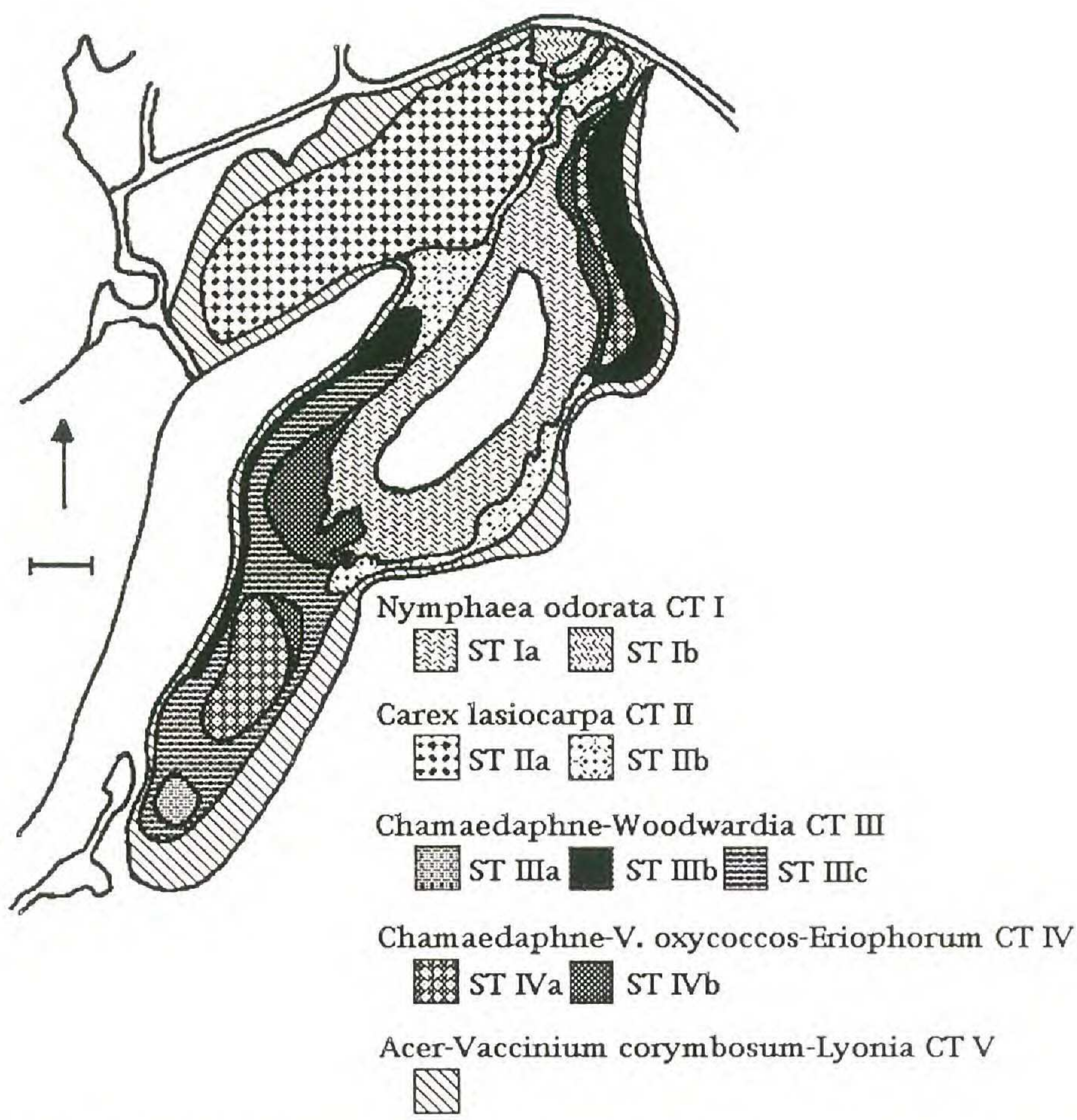

Figure 4. Vegetation map of Pequawket Bog showing five cover types(CT) and nine subtypes(ST). Scale bar equals 50 m

Potamogeton confervoides has been reported as occurring in acidic waters of New England along the coastal plain, and is often associated with *Eleocharis robbinsii* (Hellquist and Crow, 1980). It has been regarded as rare and endangered for other New England states including Connecticut, Maine, and Vermont. However, it is relatively common in New Hampshire and Massachusetts (Hellquist and Crow, 1980)

Carex lasiocarpa Cover Type (CT II)

The *Carex lasiocarpa* cover type, occupying an extensive area in the peatland particularly to the northwest of the pond, forms an open, sedgy meadow, or fen. It is also found around the pond margin in certain areas, presumably serving as the pioneer association of the floating mat (Figure 4). Compared to other areas in the peatland this portion of the mat is noticeably wetter, often with pools of standing water. The 83 samples of the total 287 plots clustered into this cover type are based primarily on the presence of *Carex lasiocarpa*. However, species such as *Vaccinium macrocarpon*, *Peltandra virginica*, *Triadenum virginicum*, *Carex utriculata* (=*C. rostrata* var. *utriculata*), *Sagittaria latifolia*, *Pogonia ophioglossoides* and *Myrica gale* are classified by TWINSPAN as preferential to this group as well. Mean percent cover and percent frequency of the dominant species in this cover type are listed in Table 2. *Carex lasiocarpa*, dominating this association with 38% cover on average, is a strongly rhizomatous, clonal species, as are the majority of the dominant species in this zone. Although *Myrica gale* and *Chamaedaphne calyculata* are quite dominant, it is largely the importance of the herbaceous species that give this cover type its character. Many of the herbaceous species show a relatively low cover value, but have a high frequency.

While *Carex lasiocarpa* and many of the associated species of this cover type are present at Pequawket Bog, this vegetation type is noticeably absent at nearby Heath Pond Bog (Fahey, 1993). No zone there resembles a sedgy meadow. Instead, the pioneer cover type invading the open water is dominated by *Chamaedaphne calyculata*. The pH of the pond water and shape of the basin probably have an important role in this difference between these two bogs. Vitt and Slack (1975) found pH of pond water to be an important factor

Table 2. Mean percent cover and percent frequency of dominant and subdominant species in the *Carex lasiocarpa* cover type (CT II).

Species	Mean % Cover	% Frequency
Sphagnum spp.	86	100.0
*Carex lasiocarpa**	39	92.8
Myrica gale	15	78.3
Chamaedaphne calyculata	15	71.1
Vaccinium macrocarpon	13	55.4
Peltandra virginica	7	39.8
Sagittaria latifolia	7	39.8
Carex utriculata	5	34.9
Aster nemoralis	3	20.5
Andromeda glaucophylla	3	15.7
Nymphaea odorata	3	12.0
Pogonia ophioglossoides	2	42.2
Triadenum virginicum	2	28.9
Rhyncospora alba	1	30.1
Juncus pelocarpus	1	16.9
Sarracenia purpurea	1	16.9
Symplocarpus foetidus	1	16.9
Utricularia intermedia	1	16.9
Drosera intermedia	1	13.3
Dulichium arundinaceum	1	13.3
Acer rubrum	1	12.0
Vaccinium oxycoccos	1	12.0
Scheuchzeria palustris	1	9.6
Carex stricta	1	8.4
Cladium mariscoides	1	8.4
Eriophorum tenellum	< 1	9.6
Sparganium americanum	< 1	6.0

*= indicator species for CT II

in influencing the species composition of the mat encroaching on the open water in northern Michigan bogs. They found *Carex lasiocarpa* to be the primary species occupying mats encroaching on the open water of bog ponds where the water was relatively alkaline, usually with a pH greater than 7.0, (the Alkaline Lake Edge Zone). In lakes with an acidic pH, usually ranging from 5.0 - 7.0, they found *Chamaedaphne calyculata*, *Andromeda glaucophylla*, and *Rhynchospora alba* showing higher importance values at the mat edge (the Acid Lake Edge Zone).

Crum (1988) reports that in Michigan, *Carex lasiocarpa* dominated cover types occur at the edge of lakes that possess false bottom sediments and that have relatively alkaline open water. The sediments in the pond accumulate over time and eventually lend themselves to colonization by aquatic macrophytes such as *Nymphaea* spp., *Nuphar* spp., and *Potamogeton* spp. *Carex lasiocarpa* rhizomes are able to invade these sediments particularly during drier years when the water level is lower. Vitt and Slack (1975) also make note of the presence of a false bottom in bogs supporting a *C. lasiocarpa* dominated pioneer zone. The accumulation of false bottom sediments is absent around the majority of Heath Pond.

Carex lasiocarpa has been described by many others as an important member of various bog and fen associations throughout the northern United States and Canada, (Gates, 1942; Conway, 1949; Crow, 1969; Heinselman, 1970; Vitt and Slack, 1975; Schwintzer, 1978; Vitt and Bayley, 1984). The presence/dominance of this sedge, as well as many of the other characteristic species of this cover type, have been well documented in other regions to be a reflection of more minerotrophic conditions (Heinselman, 1970; Jeglum, 1971;Vitt and Slack, 1975; Schwintzer, 1978; Vitt and Bayley, 1984; Crum, 1988).

Subtype IIa

Within the *Carex lasiocarpa* CT two cover subtypes could be recognized in the TWINSPAN analysis. The first of these, ST IIa, is found primarily as the association encroaching on the pond behind the aquatic cover type, and in areas that have been disturbed by beaver (Figure 4). Twenty-nine of the 83 cover type samples were classified into this group based on the indicator species identified by TWINSPAN, and reflected by the high percent frequency of these species: *Peltandra virginica* (96.6%), *Triadenum virginicum* (79.3%), *Rhynchospora alba* (65.5%), *Juncus pelocarpus* (44.8%) and *Utricularia intermedia* (44.8%). The dominant shrubs include *Chamaedaphne calyculata* (89.7% frequency) and *Myrica gale* (93.1% frequency). Several other species which have low cover values, but relatively high frequencies, and are important to the characterization of this subtype, include *Nymphaea odorata, Dulichium arundinaceum, Aster nemoralis, Cladium mariscoides, Drosera intermedia, Sarracenia purpurea, Sagittaria latifolia, and Pogonia ophioglossoides* . A relatively higher cover value (9%) for *Nymphaea odorata* in this cover subtype resulted from some plots falling on the edge of the pond or overlapping larger channels.

Two isolated patches of *Menyanthes trifoliata* were also observed in this cover subtype at the extreme ends of the pond, although transects did not intersect these sites. This species has been reported in the literature as typically having a very narrow niche within the peatland ecosystem, and is usually restricted to the lake edge (Dansereau and Segadas-Vianna, 1952) and/or to inflow/outflow channels (Vitt and Bayley, 1984). In northwest Ontario, Vitt and Bayley (1984) describe a *Sphagnum papillosum-Menyanthes trifoliata* community type which shows this pattern, and has some floristic similarities to the *Carex lasiocarpa* cover type, with the dominance of *Carex lasiocarpa* and *Myrica gale*. In northern Minnesota, Heinselman (1970) lists it as an indicator of weakly minerotrophic waters with a pH range of 4.3-5.8.

There are strong floristic similarities of this subtype to the

Alkaline Lake Edge Zone described by Vitt and Slack (1975) for northern Michigan, and to the *Carex lasiocarpa* mats described by Conway (1949) in central Minnesota. Many of the indicator species of this subtype may be reflecting the combined effect of a more minerotrophic condition, with a somewhat higher pH, and a higher water level (Jeglum, 1971). Vitt and Slack (1975) found the distribution of *Rhynchospora alba* to be apparently more influenced by moisture level and degree of shade, rather than by water chemistry.

Subtype IIb

The other subtype recognized by TWINSPAN in the *Carex lasiocarpa* CT is the most extensive of the two subtypes. It occupies a very large area to the northwest of the pond (Figure 4). Fifty-four samples clustered into this subtype, with the TWINSPAN preferential species including *Myrica gale* (70.4% frequency), *Chamaedaphne calyculata* (61.1% frequency), *Symplocarpus foetidus* (25.9% frequency), and *Pogonia ophioglossoides* (48.1% frequency). *Andromeda glaucophylla* and *Sarracenia purpurea* were also shown to have a strong preference for this subtype as well.

The floating mat on this side of the pond is weaker than portions of the mat in other areas of the peatland. In this meadow-like subtype, the dominant sedge *Carex lasiocarpa* has an average percent cover of 48% and 96.3% frequency, with its other major contributor to the mat, *Vaccinium macrocarpon*, with a 19% cover and 74.1% frequency. Other important species that add to the character of the subtype, whether through their cover values or frequencies include, *Myrica gale, Chamaedaphne calyculata, Sagittaria latifolia, Carex utriculata, Pogonia ophioglossoides,* and *Symplocarpus foetidus,* Species that are found more sparsely throughout the mat include *Aster nemoralis, Andromeda glaucophylla,* *Sarracenia purpurea, Vaccinium oxycoccos*, and small saplings of *Acer rubrum*. *Scheuchzeria palustris* is frequent in localized areas nearing the pond edge. *Eriophorum angustifolium*, an endangered species in New Hampshire, was also sparse, but occurred in less wet areas in this cover subtype.

The *Carex-Vaccinium macrocarpon* zone described by Crow (1969) for a southern Michigan bog has many floristic similarities to this subtype. This zone is also dominated by *Carex lasiocarpa* and *Vaccinium macrocarpon* with other similar species including *Chamaedaphne calyculata* (=*Cassandra calyculata*), *Andromeda glaucophylla, Sagittaria latifolia*, and *Sarracenia purpurea*.

A phytosociologic association dominated by *Carex utriculata* described by Dansereau and Segadas-Vianna (1952) is also similar to this subtype. They found *Carex lasiocarpa* and *C. utriculata* (=*C. rostrata* ssp. *utriculata*) to be a common association, usually in places where peat comes in contact with sand, and where there is a fluctuation in water level over the growing season. Some fluctuation of the water level was seen at Pequawket Bog, however no quantitative measurements were taken.

The *Carex lasiocarpa* CT shows up in the aerial photograph (Figure 3) as a light area; darker regions on its margin are areas where *Chamaedaphne calyculata* is more abundant. It is assumed that over time this will encroach upon the sedge meadow. This, however, will largely depend on the hydrological regime. Crow (1969) reports similar areas where *Chamaedaphne calyculata* seems to be encroaching on the *Carex lasiocarpa-Vaccinium macrocarpon* zone. Succession of this nature has been reported by Gates (1942) in peatlands of Michigan, where floating mats dominated by *Carex lasiocarpa* eventually become grounded by the accumulation of debris peat and are rapidly colonized by *Chamaedaphne* *calyculata*. This succession was not seen, however, in fens where the mat remains free floating.

Chamaedaphne calyculata-Woodwardia virginica Cover Type (CT III)

This cover type, as a whole, is quite prominent in the south and southwest portions of the mat and along the west and south sides of the pond (Figure 4). It may be characterized as an extremely dense community with the vegetation usually not more than 1 meter in height. It is largely dominated by low shrubs and *Woodwardia virginica* . The other herbaceous species found here are present either as scattered individuals throughout this zone or are restricted to patchy locations that are less densely vegetated. *Chamaedaphne calyculata* is the dominant species with a mean percent cover of 36% and frequency of 100%. Codominant *Woodwardia virginiana* was recorded as having a mean percent cover of 27% and a 88.2% frequency (Table 3). TWINSPAN identified *Woodwardia virginica*, *Carex oligosperma*, *Rhododendron canadense*, and *Kalmia polifolia* as indicator species, separating this cover type from the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum* cover type (CT IV). *Myrica gale*, *Smilacina trifolia*, *Acer rubrum*, *Aronia melanocarpa* and *Alnus incana* ssp. *rugosa* also showed more of a preference to this cover type over CT IV. *Carex trisperma* is quite dominant in this cover type as well, but it did not show a preference between the two *Chamaedaphne calyculata* dominated cover types. Other woody species important to this cover type include *Kalmia angustifolia*, *Andromeda glaucophylla*, *Vaccinium corymbosum*, *Larix laricina* and *Picea mariana*. Other herbaceous species with a minor role in this zone include *Symplocarpus foetidus*, *Eriophorum virginicum*, *Sarracenia purpurea*, *Calla palustris*

Table 3. Mean percent cover and percent frequency of dominant and subdominant species of the *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III).

Species	Mean % Cover	% Frequency
Sphagnum spp.	99	100.0
Chamaedaphne calyculata	38	100.0
*Woodwardia virginica**	26	85.4
*Rhododendron canadense**	11	52.4
Carex trisperma	11	45.1
*Carex oligosperma**	9	48.8
Myrica gale	8	52.4
Smilacina trifolia	5	20.7
*Kalmia polifolia**	4	50.0
Alnus incana ssp. *rugosa*	3	31.7
Acer rubrum	2	35.4
Aronia melanocarpa	2	26.8
Symplocarpus foetidus	2	20.7
Eriophorum virginicum	1	31.7
Kalmia angustifolia	1	17.1
Andromeda glaucophylla	1	13.4
Sarracenia purpurea	1	12.2
Calla palustris	1	9.8
Larix laricina	1	7.3
Vaccinium corymbosum	1	7.3
Picea mariana	1	6.1
Scheuchzeria palustris	1	2.4

*= indicators for CT III

and *Scheuchzeria palustris.*

A cover type somewhat similar is found at Heath Pond Bog (Fahey, 1993) where an extensive mat is by far dominated by ericaceous shrubs, *Eriophorum vaginatum* ssp. *spissum*, and scattered *Larix laricina* and *Picea mariana*. A similar cover type also occurs at Cedar Bog, in Kingston, New Hampshire (Crow, pers. obs.). However, there are few reports of *Woodwardia virginica* as a dominant constituent such as it is at Pequawket Bog and Heath Pond Bog. It has been been described by Damman and French (1987) in peatlands of the glaciated northeastern United States as only an occasional constituent of the *Sphagnum rubellum-Chamaedaphne calyculata* community, which is typically associated with oligotrophic quaking mats bordering lakes. They also describe it as an occasional constituent of the Cinnamon Fern-Highbush Blueberry Thicket. Keough and Pippen (1981) describe the vegetation of two adjacent bogs in southwest Michigan with strong floristic similarities to Pequawket Bog, including the dominance of *Woodwardia* in certain zones. They found it particularly dominant in the understory of a tall shrub zone dominated by *Aronia melanocarpa, Nemopanthus mucronata, Vaccinium corymbosum, Larix laricina*, and *Rhamnus frangula.* Crow (1969) reports it to be a minor constituent of the *Larix laricina* and *Acer rubrum* zones another southern Michigan bog.

Dunlop reported *Woodwardia* as occasional at Mud Pond Bog, found "on the fringe and in wooded zones particularly on the east and northeast sides of the bog" (Dunlop, 1983, p. 23), in what is described as the *Acer-Nemopanthus* Community Type (Dunlop, 1987). The *Carex trisperma-Kalmia angustifolia* subtype of the *Chamaedaphne* dominated cover type of Mud Pond Bog (Dunlop, 1987) shows some floristic similarities to Pequawket and Heath Pond Bog as well. Spatially they are comparable as well, as they are found between the quaking mat and the moat.

Subtype IIIa

Since the *Chamaedaphne calyculata-Woodwardia virginica* CT covers a rather large area of the peatland, it is not surprising that the TWINSPAN analysis reveals three subtypes. The first subtype, ST IIIa, occupies a relatively small area of the peatland toward the outer edge of the southwest mat (Figure

4). The map depicts this subtype as a circular zone surrounded by ST IIIc. This subtype has a very shrubby character and the area is substantially wetter in certain spots. The TWINSPAN program indicates that *Smilacina trifolia* (85.7% frequency) and *Symplocarpus foetidus* (71.4% frequency) show a high preference for this zone and were thus used by TWINSPAN as indicator species; *Sarracenia purpurea, Alnus incana* ssp. *rugosa*, and *Calla palustris* also show a preference to this subtype.

As in all of the subtypes of CT III, *Chamaedaphne calyculata* is dominant. Here it has a mean cover of 33% and frequency of 100% (Table 6). *Woodwardia virginica* has less cover on average (15%) in this zone compared to the other two subtypes. Other dominant woody species include *Myrica gale, Kalmia polifolia,* and *Alnus incana* ssp. *rugosa. Picea mariana, Rhododendron canadense,* and *Acer rubrum* are also present, but to a lesser degree. Other dominant herbaceous species include *Carex oligosperma* and *C. trisperma.* While *Calla palustris* and *Sarracenia purpurea*, do not appear dominant quantitatively, TWINSPAN indicates they are preferencial to the subtype. *Eriophorum virginicum* is also found occasionally in this zone.

There is no extensive zone at Heath Pond Bog that is directly comparable to this subtype, however, towards the moat running along Rte. 25 there is an area where *Smilacina trifolia, Woodwardia virginica, Chamaedaphne calyculata,* and other ericaceous shrubs are quite prominent.

While this zone is probably too narrowly defined to be directly compared to other described communities, the indicator species of this subtype may be reflecting certain ecological conditions or combinations of these conditions. Typically areas near the moat are influenced more by the mineral rich telluric water than the zones further inward on the mat. It is well documented in other geographical regions that *Alnus* *incana* ssp. *rugosa* is common in the more mineral rich areas of peatlands or in fens (Conway, 1949; Dansereau and Segadas-Vianna, 1952; Heinselman, 1970; Schwintzer, 1981, Vitt and Bayley, 1984; Crum, 1988). *Calla palustris* is often a common species associated with *Alnus* in wet moats (Crum, 1988). *Symplocarpus foetidus* is typical of more nutrient rich, wet areas as well. However, in Michigan, *Smilacina trifolia* is usually described as a subordinate in associations which are largely forested and shady, or at least in the taller shrub zones toward the moat (Gates, 1942; Crum, 1988). Worley (1981) uses the presence of *Smilacina trifolia* as one of the indicators to designate the moat in Maine peatlands.

Subtype IIIb

The second subtype (ST IIIb) is found usually in the sunniest and somewhat wetter areas of the *Chamaedaphne calyculata-Woodwardia virginica* cover type (Figure 4). In the delineation of this subtype from the others, TWINSPAN identified *Carex oligosperma* and *Chamaedaphne calyculata* as indicator species.

Chamaedaphne calyculata and *Woodwardia virginica* dominate with a mean cover of 51% and 26% respectively and both have 100% frequency. *Carex oligosperma* is quite prominent as well, with a mean cover value of 17% and frequency of 71.4%. Other dominant woody species that characterize this subtype include *Rhododendron canadense* and *Myrica gale*, and to a lesser extent *Alnus incana* ssp. *rugosa, Kalmia polifolia, Vaccinium corymbosum, Acer rubrum, Aronia melanocarpa*, and *Kalmia angustifolia*. Other herbaceous species include *Carex trisperma, Eriophorum virginicum, Symplocarpus foetidus*, and *Scheuchzeria palustris*.

Scheuchzeria palustris, interestingly, occurs in certain locations on the mat that are adjacent to the pond, particularly on the east side, but not in the southwestern portion of the bog mat. The species was, however, found on the opposite side of the pond in the *Carex lasiocarpa* CT, especially nearer the pond margin. Another species, *Eriophorum angustifolium*, occasionally found scattered within this subtype, also was found in certain locations of the *Carex lasiocarpa* CT.

Heath Pond Bog (Fahey, 1993) has scattered patches throughout the extensive mat west of the pond which are similar to this subtype, characterized as being less densely occupied by shrubs, with a relatively open and slightly wetter area of Heath Pond Bog. *Eriophorum angustifolium* is is found scattered throughout this mat. However, *Myrica gale* and *Alnus incana* ssp. *rugosa* are not present, nor is *Scheuchzeria palustris*.

Dunlop (1987) does not report any cover type at Mud Pond Bog similar to this. However, Vitt and Bayley (1984) describe an association similar to this in northwestern Ontario. It is dominated by *Chamaedaphne calyculata*, *Carex oligosperma*, and *Scheuchzeria palustris*, but *Woodwardia virginica* is lacking. That peatland was characterized with an average pH of 4.37 (ranging from 4.2-4.8). They found the distribution of *Scheuchzeria palustris* in the peatland apparently to be unrelated to pH. However, *Carex oligosperma* appeared to be an indicator of oligotrophic habitats with low pH values.

Schwintzer (1981) found *Carex oligosperma* and *Chamaedaphne calyculata* to be the most characteristic species of the "field layer" in northem Michigan bogs which were highly acidic (pH 3.8-4.3) and low in Ca^{++} and Mg^{++} (1.2-3.7 mg/L and 0.3-0.6 mg/L respectively). Vitt and Slack (1975) found *Carex oligosperma* occupying the Acid Lake Edge Zone, the Open Mat Zone and the Closed Mat Zone, however it was most dominant in the zones further back from the lake edge.

Subtype IIIc

The third subtype of the *Chamaedaphne calyculata-Woodwardia virginica* CT is found to be quite dominant in the southern and southwestern portions of the mat, and on the mat along the east side of the pond (Figure 4). It is characterized as being a rather dense, woody zone, and much of it difficult to walk through. TWINSPAN identified *Kalmia polifolia* (69.7% frequency), *Aronia melanocarpa* (51.5% frequency), *Acer rubrum* (54.5% frequency) and *Carex trisperma* (72.7% frequency) as species highly preferential to this subtype. *Vaccinium oxycoccos, Andromeda glaucophylla* and *Kalmia angustifolia* showed a preference here as well. One noticeable character to this subtype is the dominance of *Woodwardia virginica*, with a mean cover of 32% and a frequency of 84.8%. Compared to the other subtypes within the *Chamaedaphne calyculata-Woodwardia virginica* CT, this is the only zone where *Woodwardia virginica* has a higher mean percent cover than *Chamaedaphne calyculata*. Other dominant woody species that characterize this zone include *Chamaedaphne calyculata, Rhododendron canadense, Myrica gale, Kalmia polifolia, Acer rubrum*, and *Aronia melanocarpa*. The dominant herbaceous species include *Carex trisperma* and *Eriophorum virginicum*. Species that play a less significant role, though still important to the character of this subtype, include *Andromeda glaucophylla, Alnus incana* ssp. *rugosa, Kalmia angustifolia, Vaccinium oxycoccos, Carex oligosperma, Smilacina trifolia*, and *Sarracenia purpurea*.

A similar association is found at Heath Pond Bog (Fahey, 1993) on the portion of the mat encircling the pond, between the quaking mat and the moat, and in areas closer to the moat along the bordering highway.

The distribution of *Carex trisperma*, an indicator species, seemed to be particularly related to areas of very firm peat, and a more or less closed canopy. This observation is supported by the findings of Vitt and Slack (1975) who reported that the distribution of this sedge in northern Michigan bogs seemed to be related to shade. The sedge was found to be more abundant in areas where *Picea* and *Larix* became more important. Crum (1988) also reports its abundance enhanced by the shade created by the two conifers, on drier mounds. Vitt and Bayley (1984) describe a *Smilacina trifolia-Ledum groenlandicum-Carex trisperma* community type in Ontario which was characteristically shady as well.

Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum Cover Type (CT IV)

The *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum* cover type (CT IV) occurs in regions of the peat mat which are apparently less consolidated, as they have a noticeably more quaking feel to them. Figure 4 shows this zone on the northeast side of the pond between the aquatic cover type and the *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III). On the southwest mat CT IV is found roughly in the center of that region, encircled by CT III, and also as the pioneer association encroaching on the pond at the southern and northeast sides. While *Chamaedaphne calyculata* is a dominant of this cover type, it has a much smaller stature than in the *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III). It usually does not attain heights much over 30 cm. Compared to CT III this zone is strikingly more open and less shrubby. Because of its openness and low stature of the woody species, Crum (1988, p. 61) refers to similar communities such as this as the "Sphagnum Lawn Community".

The dominant species that characterize this vegetation zone include *Chamaedaphne calyculata, Vaccinium oxycoccos,* and *Eriophorum virginicum* (Table 4). It was the high degree of preference to this zone of the latter two species which TWINSPAN used to classify this cover type from CT III. *Andromeda glaucophylla* showed a preference to this zone as well. *Carex trisperma* is an integral member of this cover type also, but it does not necessarily show a preference to this zone. It is also quite dominant in the *Chamaedaphne calyculata-Woodwardia virginica* cover type, and is found most often in the transition zone between these two cover types. Other subdominant woody species of this cover type are *Myrica gale, Kalmia polifolia, Larix laricina*, and *Picea mariana*. The subordinate herbaceous species include *Drosera rotundifolia, Rhynchospora alba, Woodwardia virginica, Decodon verticillata, Eriophorum vaginatum* ssp. *spissum,* and *Peltandra virginica*. For mean percent cover and percent frequency of these species see Table 4.

Cover types of this nature are very common in peatlands, especially in kettle-hole bogs. In Michigan, Vitt and Slack (1975) describe an Open Mat Zone, adjacent to the edge zone of alkaline lakes, with strong floristic similarities. Along with *Chamaedaphne calyculata, Vaccinium oxycoccos* was the most dominant vascular plant. Its distribution within the bogs was apparently related to non-shaded habitats which were low in pH and cation concentration. These locations also had little change in microtopography, and were fairly wet. Other similarly dominant species included *Kalmia polifolia, Andromeda glaucophylla, Rhynchospora alba, Drosera rotundifolia* and *Eriophorum virginicum*. Although Vitt and Slack (1975) associated this community type with alkalinity of the lake water, the waters of Pequawket Bog's pond are not alkaline. Based on the species present, however, the pond water is probably fairly minerotrophic, and the pH is relatively high (5.69) compared to the other cover types.

Table 4. **Mean percent cover and percent frequency of dominant species in the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum* cover type (CT IV).**

Species	Mean % Cover	% Frequency
Sphagnum spp.	100	100.0
Chamaedaphne calyculata	43	100.0
*Vaccinium oxycoccos**	10	88.9
Carex trisperma	9	38.1
*Eriophorum virginicum**	7	88.9
Andromeda glaucophylla	5	34.9
Myrica gale	3	23.8
Drosera rotundifolia	2	19.0
Picea mariana	2	11.1
Woodwardia virginica	2	11.1
Decodon verticillata	2	9.5
Larix laricina	1	14.3
Rhynchospora alba	1	14.3
Kalmia polifolia	1	12.7
Eriophorum vaginatum ssp. *spissum*	1	7.9
Peltandra virginica	1	7.9

* = indicator species for CT IV

Subtype IVa

Two subtypes were discernable within the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum* CT. The first subtype (ST IVa) occupies the center of the back south-southwest mat, and also along the mat on the northeast side of the pond (Figure 4). On the southwest mat, although it is some distance away from the open water of the pond, it still has a noticeable quaking feel to it. The basin profile data of this mat (Figure 5) indicate that this area is the center of a relatively recent closed basin. TWINSPAN found *Carex trisperma, Eriophorum virginicum* and *Chamaedaphne* *calyculata* highly preferential to this subtype over ST IVb. Although *Chamaedaphne calyculata* is dominant in both subtypes it averaged a much higher cover value (55% cover, 100% frequency) in ST IVa in contrast to ST IVb (32% cover, 100% frequency). Other species that show a preference to this subtype include *Kalmia polifolia* and *Larix laricina.*

Chamaedaphne calyculata is the clearly the dominant woody species. Other dominant woody species include *Vaccinium oxycoccos, Larix laricina, Kalmia polifolia,* and *Picea mariana* are also found here, but toward the transition into the *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III). The dominant herbaceous species include *Eriophorum virginicum* and *Carex trisperma,* the latter also found more frequently toward the transition into CT III.

Platanthera blephariglottis, rare within the peatland, is found sparsely in this cover type, usually nearing the transition zone between between CT III and this cover type. Scattered individuals were found in the south-southwest mat and on the northeast side of the pond.

Subtype IVb

The second subtype is found in regions of the peatland closer to the pond on the quaking mat (Figure 4), and is often the lake edge association in locations where *Carex lasiocarpa* is not as abundant. It extends back from the edge at varying distances ranging from 0.5 to approximately 40 meters. It is less homogeneous than ST IVa. An increase in abundance and frequency of species such as *Andromeda glaucophylla* (66% frequency), *Myrica gale* (36.4% frequency), *Drosera rotundifolia* (33.3% frequency) and *Rhynchospora alba* (27.3% frequency) distinguishes this subtype from ST IVa. *Eriophorum virginicum* is also quite dominant in this subtype. Other less dominant species found here include *Decodon* *verticillata* and *Woodwardia virginica,* as well as *Peltandra virginica*, which was absent from ST IVa.

Although not represented in the sampling, small patches of a somewhat exclusive association of *Utricularia cornuta, Vaccinium oxycoccos, Drosera rotundifolia, Xyris montana,* and sometimes *Calopogon tuberosus* were present in this subtype, particularly in especially wet and mucky areas. The substrate of these mucky areas was not as consolidated as in other parts of this subtype, and may not support the weight of unsuspecting field botanists. A small localized area, close to the pond on the southsouthwest mat, possesses the same characteristics, and when probed with a peat sampler, was found to be approximately 10 meters deep. An interesting feature to this location in particular was the sizeable population of about 200 individuals of *Calopogon tuberosus*.

A comparable association was found to be quite common at Heath Pond Bog (Fahey, 1993) as well, particularly the narrow floating mat immediately adjacent to the lake-edge.

ST IVb as a whole is also floristically similar to what Dunlop (1987) reported in southern New Hampshire as a *Vaccinium oxycoccos-Rhynchospora alba* subtype, found adjacent to the lake edge of Mud Pond Bog.

The close proximity to the edge probably explains the increased abundance of *Andromeda glaucophylla* and *Myrica gale*, species that reflect, at least in other regions of North America, a weakly minerotrophic condition (Jeglum, 1971; Schwintzer, 1978). Dansereau and Segadas-Vianna (1952) found *Andromeda glaucophylla* to occur often in the wettest regions of the *Chamaedaphne calyculata* dominated association in Canada. As mentioned previously, *Rhynchospora alba* has a distribution in peatlands which seems to be governed by moisture and the intolerance of shade rather than water chemistry (Vitt and Slack, 1975).

Acer rubrum-Vaccinium corymbosum-Lyonia ligustrina Cover Type (CT V)

This cover type is found largely around the outer periphery of the peatland. Typically it extends from the base of the upland out on to the mat in varying widths (Figure 4). Many of its constituents integrade strongly with the *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III), but a high preference of *Acer rubrum, Vaccinium corymbosum,* and *Lyonia ligustrina* TWINSPAN distinguishes this cover type. It is dominated primarily by tall shrubs over 1.5 meters in height, and an understory which is quite variable. A moat of standing water is found at the immediate base of the upland, often quite deep in places. Although *Chamaedaphne calyculata* has the highest cover (18%) and frequency (79.4) value, this zone has been named after the taller shrubs based on their relative high cover and frequency in combination with their relative uniqueness to this zone (Table 5).

Other important tall, woody species (>1.5 m) that characterize this cover type include *Alnus incana* ssp. *rugosa, Nemopanthus mucronata, Ilex verticillata, Rhododendron canadense,* and *Aronia melanocarpa. Betula populifolia, Cephalanthus occidentalis* and *Viburnum cassinoides* are found less frequently. Other low growing shrubs include *Myrica gale, Kalmia angustifolia,* and *Spiraea latifolia.* The more typical herbaceous species include *Osmunda regalis, Osmunda cinnamomea, Carex stricta, Symplocarpus foetidus, Carex trisperma, Rubus hispidus, Lysimachia terrestris, Triadenum virginicum, Utricularia intermedia, Drosera rotundifolia*, and *Juncus pelocarpus.*

The moat at Heath Pond Bog (Fahey, 1993) is floristically very similar, except for the shrubby moat area which has been extensively disturbed by beavers. In another New Hampshire bog (Dunlop, 1987) the *Ilex verticillata-Acer-Carex* *canescens* community type occupying the moat shows floristic similarities, but the importance of *Vaccinium corymbosum* and *Lyonia ligustrina* are not as great.

Table 5. Mean percent cover and percent frequency of dominant species in the *Acer rubrum-Vaccinium corymbosum-Lyonia ligustrina* cover type (CT V).

Species	Mean % Cover	% Frequency
Sphagnum spp.	63	97.4
Chamaedaphne calyculata	18	79.5
*Vaccinium corymbosum**	12	64.1
*Lyonia ligustrina**	12	59.0
Osmunda regalis	12	30.8
Alnus incana ssp. *rugosa*	9	53.8
*Acer rubrum**	8	74.4
Osmunda cinnamomea	8	23.1
Myrica gale	7	46.1
Nemopanthus mucronata	7	35.9
Carex stricta	7	33.3
Ilex verticillata	7	25.6
Rhododendron canadense	6	59.0
Aronia melanocarpa	4	48.7
Symplocarpus foetidus	4	43.5
Carex trisperma	4	28.2
Betula populifolia	3	20.5
Woodwardia virginica	3	17.9
Cephalanthus occidentalis	3	7.7
Rubus hispidus	2	30.8
Lysimachia terrestris	2	28.6
Kalmia angustifolia	2	25.6
Triadenum virginicum	2	25.6
Viburnum cassinoides	2	23.1
Utricularia intermedia	2	20.5
Drosera rotundifolia	1	23.1
Spiraea latifolia	1	23.1
Juncus pelocarpus	1	20.5

* = indicator species for CT V

Vitt and Slack (1975) reported a tall shrub zone (the Marginal Moat Zone) encircling bogs in northern Michigan. This community type consisted of similar species, but with different abundances. They also noted that this zone appeared to be highly variable, but was primarily dominated by *Ilex verticillata, Nemopanthus mucronata, Viburnum cassinoides*, and occasionally *Osmunda regalis*.

Floristically this cover type strongly resembles the Cinnamon Fern-Highbush Blueberry Thicket described by Damman and French (1987), with some variation. This type of tall shrub thicket occurs in locations with seasonal water-level fluctuations, and that are heavily influenced by minerotrophic water from the surrounding upland or seepage (Damman and French, 1987). The community was also characterized as having a well developed ground layer of vegetation.

Basin Profile

Probings of the peat mat at 10 meter intervals along transect 1 resulted in a profile of the bog basin (Figure 5). The profile shows an apparent basin of a former pond which has been completely blanketed by the bog mat. The basin measures approximately 11 meters at its deepest point. Figure 5 shows a vegetation map of the south and southwest portion of the peatland showing transect 1, and the vegetation types through which it runs, for comparison with the same zones shown on the basin profile. At the deepest part of the basin the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginicum* cover type (CT IV) occupies a relatively large area, approximately 110 m long; ST IVa occupies the majority of this area, particularly where the basin is deepest. Surrounding this zone is the *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III), an area that corresponds with a more shallow basin. Toward the pond edge the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginianum* CT is represented by ST IVb, corresponding with a basin depth of approximately 2-7 meters. At the outer edge of the mat the *Acer rubrum-Vaccinium corymbosum-Lyonia ligustrina* cover type (CT V) is found

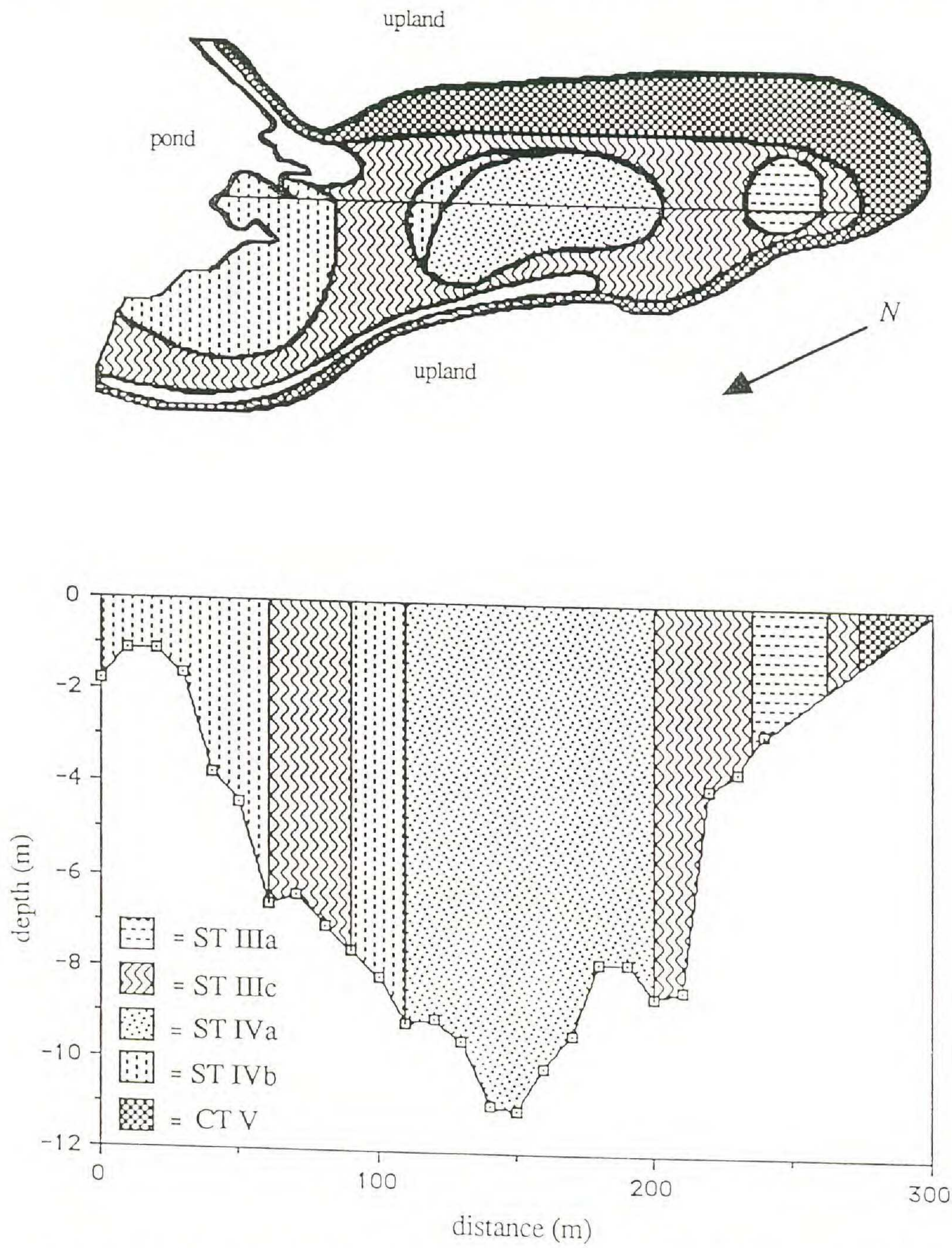

Figure 5. Basin profile (below) along transect 1 at the southwest mat in relation to the vegetation types.

in the areas that show the shallowest probings. This pattern seems to reflect the classic theory of lake-fill, or quaking bog succession.

Motzkin and Patterson (1991) recently described the vegetation patterns in Acadia Bog, a Massachusetts moat bog. They found a correlation of vegetation types to depth of sediment accumulation and distance from shore. Although the species composition of the vegetation types of the two bogs are not comparable, Pequawket Bog likewise shows a similar relationship (Figure 5) in the southernmost portion of the southwest mat.

Probings of the basin depth along transect 8 through the *Carex lasiocarpa* cover type (CT II), showed relatively shallow readings throughout. Depths ranged from 1.0 nearer the edge to 3.5 meters closer to the pond margin. In probing this section the bottom felt like very loose sand.

pH

It has been well documented that pH of the pond and mat waters play an important role in the distribution of species within a peatland (Jeglum, 1971; Vitt and Slack, 1975; Heinselman, 1970; Schwintzer, 1978, 1981; Vitt and Bayley, 1984; and others). Table 6 shows the mean pH values of each cover type.

The overall aquatic *Nymphaea odorata* cover type (CT I) has the highest pH, 5.58. The water of the open pond within ST Ia averaged 5.69. However, the pool at the northern end of the peatland, occupied by ST 1b, was more acidic, averaging 5.37.

On the outer edge of the bog the moat waters of the *Acer rubrum-Vaccinium corymbosum-Lyonia ligustrina* cover type (CT V) are also relatively less acidic than other cover types in the peatland, averaging 5.13. Moat waters are typically less acidic and more mineral rich as a result of the influence of telluric waters entering from the upland.

The pH of the *Carex lasiocarpa* cover type (CT II) averaged 4.55, but there were considerable differences in the pH among its subtypes. ST IIa, adjacent to the open pond water, averaged 5.46, while ST IIb averaged 4.23. This may be due to the relative distance away from an influence of less acidic pond water as well as to an abundance of *Sphagnum* spp. acidifying the mat waters.

The cover types of the south-southwest mat, which appear to have covered an old pond basin (Figure 5), and along the west and northeast sides of the pond, generally show lower pH levels. The *Chamaedaphne calyculata-Woodwardia virginica* cover type (CT III) is less acidic, with a pH of 4.18, than the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginiana* cover type (CT IV) averaging 3.89.

Vitt and Slack (1975) measured pH, as well as cation concentration, along a transect from the pond edge to the base of the upland and found these to be very influential in the distribution of plant species and communities. The pH was highest in the pond water and at the alkaline mat edge. As the distance increased from the water's edge, across the mat, the pH dropped dramatically, but showed an increase again near

.and in the moat water. A similar pattern was observed for Pequawket Bog

While the pH values throughout the Pequawket peatland are very low over all, this is to be expected for regions with noncalcareous bedrock. Lakes of New Hampshire have naturally acidic conditions, as a result of surrounding acidic bedrock, such as granite.

Species Density

Some ecologists have investigated the variations in species density, or richness, within and between peatland ecosystems (Heinselman, 1970; Schwintzer, 1981), and have attempted to explain the differences observed.

At Pequawket Bog, the mean species density (number of species per m^2) was calculated for each subtype and the moat cover type (Figure 6). The *Nymphaea odorata* CT is quite depauperate with ST Ia and ST Ib averaging 4.4 (± 1.4) and 4.6 (± 1.5) species/m^2 respectively. Conversely, within the *Carex lasiocarpa* CT, ST IIa has a noticeably higher species density of 11.2 (± 2.9), compared to all the other cover types and subtypes. Of the *Chamaedaphne calyculata* dominated subtypes the ST IIIa has the highest species density with 8.9 (± 1.9) on average, while ST IVa averaged only 4.2 (± 2.7) species/ m^2 The *Acer rubrum-Vaccinium corymbosum-Lyonia ligustrina* CT, the tall shrub zone occupying the moat, averaged 8.4 (± 2.7) species/ m^2.

A possible explanation for the differences in species density between subtypes may be found when applying Grime's (1979) model for the control of species density in herbaceous vegetation. Although this model is for herbaceous vegetation and the validity of applying it to a woody community may have its limitations. This model proposes that vegetation in the presence of moderate levels of either stress or disturbance, or both, has an "increase in species density by reducing the vigor of potential dominants, thus allowing subsidiary species to co-exist with them" (Grime, 1979, p. 162). As these stresses or disturbances approach extremes, a decline in species density is found. Under extreme conditions only a small number of species appear to be able to survive.

Table 7 compares the vegetation types based on statistically significant differences in species density. Because many of the environmental parameters which could influence a stress or stimulus on the component species of the vegetation in the peatland were not sampled, and because levels of disturbance where not quantified, reasons for differences between vegetation types can only be speculative. However, the values measured for pH lend themselves to a possible explanation of differences between certain subtypes, as do observations of some disturbances, particularly by beavers. Grime (1979)

Table 7. A comparison of the vegetation types in Pequawket Bog showing significant differences in species density at the 95% confidence level ($p < 0.05$).

	ST Ia	ST Ib	ST IIa	ST IIb	ST IIIa	ST IIIb	ST IIIc	ST IVa	ST IVb
ST Ia									
ST Ib	---								
ST IIa	*	*							
ST IIb	---	---	*						
ST IIIa	*	*	---	---					
ST IIIb	---	---	*	---	*				
ST IIIc	*	*	*	---	---	*			
ST IVa	---	---	*	*	*	---	*		
ST IVb	---	---	*	---	---	---	*	---	
CT V	*	*	*	---	---	*	---	*	---

* significant at 95%

shows there is a relationship between the pH of different habitats and species density. Other possible influences may include fluctuations in water level, conductivity, alkalinity, and aeration.

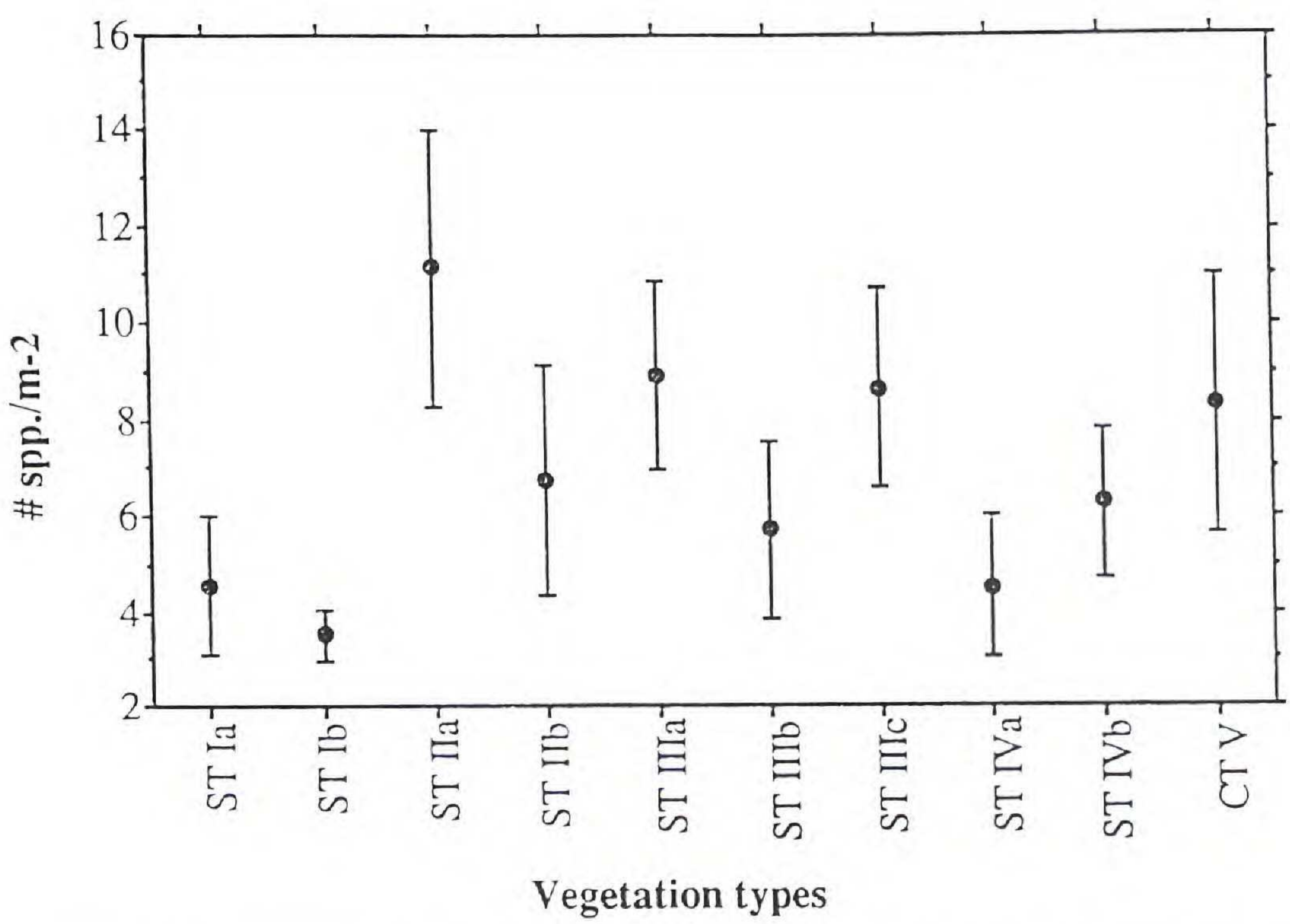

Figure 6. Average species density, expressed as number of species per square meter (for all vegetation cover types and subtypes

Within the *Carex lasiocarpa* CT, ST IIa shows a significantly higher species density than all other vegetation cover types except for ST IIIa. The areas in the peatland where ST IIa is found are on the edge of the pond, which is subjected to water level fluctuations, and in areas that show considerable disturbance by beaver (Figure 4). Likewise, the small area occupied by ST IIIa shows signs of beaver disturbance

Schwintzer (1981) found a relationship between species density of vascular plants in three northern Michigan wetland types (bogs, fens, and conifer swamps) and degree of telluric water influence. In bogs with little influence from telluric waters, a low species density was found due to the stressful, nutrient-poor environment. At Pequawket Bog, within the *Chamaedaphne calyculata-Vaccinium oxycoccos-Eriophorum virginiana* CT, ST IVa had a significantly lower richness than many other mat vegetation types, and is found in an area of the southwest mat than is furthest away from the upland. It can be assumed that this location is also relatively poor in telluric minerals as reflected by its low pH (3.72). Any inflowing telluric water from the upland probably does not reach the center of the mat; additionally, there is no export of acids out of this area. Schwintzer (1981) reports substantially higher species density in fens and conifer swamps with a moderate to strong influence of telluric water. Similarly, at Pequawket Bog higher species richness was seen in areas of the moat and on the edge of open water, where the pH is higher. Schwintzer also points out that there are other factors that influence species density, such as tree layer, water level fluctuations, and range and number of microsites provided by microrelief.

Heinselman (1970) compared the richness of seven different peatlands in northern Minnesota and found an increase in number of species as the flow-through conditions increased. The stimulus of the increase is thought to be due to the input of mineral nutrients and a reduction in anaerobic conditions.

SUMMARY

In summary, Pequawket Bog is a level peatland complex with an aquatic community, a sedge meadow, two areas with more typical bog flora, (*Sphagnum* spp. and low ericaceous shrubs dominating), and a tall shrub or moat cover type. The five major cover types reflect general vegetational and floristic similarities with other level peatlands in northeastern North America. With a diverse flora of 109 vascular plants, the peatland complex might be best classified as a "rich fen".

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Figure 1. Photograph of herbarium specimen of Marsh Sow-thistle x 1/3